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A Study of Covid-19 Cases using SIR Model in Nepal

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Abstract:

Due to the growing world population and their mobility all over the world, the risk of infectious disease is high. From 2019, there is a common big issue of COVID-19. Nepal is also a country affected by COVID-19. For the study, the secondary data of COVID-19 from January 2021 to January 2023 were extracted from the Government of Nepal, Ministry of Health, and population Internet sites https://covid19.mohp.gov.np/ or https://heoc.mohp.gov.np, the WHO Coronavirus (COVID-19) Dashboard website: https://www.who.int, and the COVID-Coronavirus Statistics—Worldometer web site: https://www.worldometers.info>coronavirus. The secondary COVID-19 data collected for this study from official offices and sources was analyzed for readability and comprehension. The solution of a renowned model, SIR, was also taken. The computer software MATLAB was used to plot the graphs with the help of parametric values obtained from the real data. From the graphical results, we found that the trend of COVID-19 cases is increasing in May 2020 to November 2020, decreasing in November 2020 to April 2021, increasing in 2021 to June 2021, and decreasing in June 2021 to July 2021. Infected cases are high in November 2020 and in May to June 2021. Recovered cases are high in November to December 2020 and in May to June 2021. We also found that the predicted infected and recovered disease cases from the model are almost matched with the infected and recovered disease cases of real data for COVID-19 in Nepal.

Keywords: Infected, Recovered, COVID-19, SIR, MATLAB.

1. Introduction

1.1 Background Study

The first instance of the Corona Virus Disease (COVID-19) was discovered in Wuhan City, China, in December 2019 [23]. The COVID-19 wave was labeled as a world pandemic by the World Health Organization (WHO) on March 11 [24]. It swiftly expanded to other nations, both inside and outside of Asia. SARS-CoV-2, or the Severe Acute Respiratory Syndrome Corona Virus, is the pathogen that has caused the global pandemic of Corona Virus Disease 2019 (COVID-19), one of the most contagious diseases in recent memory [7].

On January 24, 2020, the first victim of COVID-19 was formally confirmed after a Nepalese student who had come back from China to Nepal reported a positive result from the WHO recommendation lab in Hong Kong [3, 15, 12]. The second incident was found on March 23, 2020, in a 19-year-old woman who had just arrived from France through Doha, Qatar, and was discovered about two months behind [15].

The infectious and harmful disease COVID-19 is caused by the virus SARS-CoV-2. The vast majority of virus-infected people will experience a light to serious respiratory illness and will get better without the demand for particular treatment. But occasionally, individuals will develop serious illnesses and be in need of medical observation. Seniors and people with underlying medical situations such as diabetes, cardiovascular disease, cancer, or long-term respiratory difficulties are more susceptible to major illnesses. No matter their age, anyone can contract COVID-19, suffer serious sickness, or pass away [22].

The virus can open out from the lips or nose in minute fluid particles when an infected person speaks, sings, sneezes, or breathes. These particles range in size from small aerosols to larger respiratory droplets. Following a respiratory protocol is essential, such as coughing into a bent elbow, staying inside your house, and resting until you feel better [22].

Until January 30, 2023, there have been 753325928 confirmed cases and 6836537 death cases, and as of January 30, 2023, there have been 165736 confirmed cases and 1015 death cases daily in the world, according to the WHO global situational dashboard (WHO Dashboard). As of January 30, 2023, there were 3 confirmed cases and 0 death cases, in accordance with the Ministry of Health and Population (MoHP) of Nepal, and until January 30, 2023, there were 1001099 confirmed cases and 12020 deaths in Nepal. Mathematical modeling is a highly versatile tool in the epidemiology of infectious diseases that enables the detection of epidemic patterns, estimation of epidemic functioning, as well as the impact of interference like pharmaceutical therapy, vaccination, quarantine, social isolation, and hygiene precautions in a dynamic setting, offering affordable options.

One of the most popular approaches to expanding the SIR model is to include compartment E, which stands for people who have been exposed to the illness but have not yet contracted an infectious condition [14]. For their research on the spread of malaria, Osman and Adu built the SEIR model, a comparable model. To establish efficient control measures and regulations, mathematical models that offer insights and forecast the pandemic are essential [18].

Here, we've suggested using a novel SIR model with unique properties. In our analysis, we used time-series COVID-19 information for Nepal from WHO, 2023, that covered the period from March 2020 to July 2021. To comprehend the consequences and gauge the disease's trend in Nepal, these datasets were used to update the SIR model's parameters. Dataset-provided graphs and the SIR model have been contrasted. We were able to determine how COVID-19 moved across the country using estimates for the quantity of deaths, susceptible, infected, and removed populations over time.

Finally, we came to a conclusion and talked about the findings of our study and the comparison of actual data with the disease spread model.

1.2 Literatures Review

The first mention of human coronaviruses (HCoVs) dates back to the middle of the 1960s, when HCoV-229E [8] and HCoV-OC43 [27] were isolated from people who had the common cold. MERS-CoV, SARS-CoV, and SARS-CoV-2 are the three respiratory viruses that cause severe acute respiratory syndrome, one of the seven types of CoVs that have since been found in humans and are all thought to have originated from bats [9].

Local performance of the SIR model real data has been found by Youssef and Hassan in 2022 [26]. A reliable approximation of the SIR model's Saudi Arabian parameters during a 275-day period (from the beginning of April 2020 to the last of December 2020) has been produced. The parameters were approximated using the real data that had been collected and utilized to forecast the values for the following period. For the traditional SIR models, the performance of the typical fourth-order Runge-Kutta algorithm has been taken into account throughout various time periods. The success of the treatment was demonstrated by comparing the recorded real data with the projected values for the examined period. Within the estimated parameter values, the mathematical characteristics and beginning conditions have been taken into account. Lockdown and social distancing attitudes have been demonstrated.

Brazilian data from February 25, 2020, to March 30, 2020, was utilized by Saulo and Daniel 2020 to estimate and predict how the COVID-19 epidemic will develop [17]. Their research concentrated on the early stages of pandemics, which are when the epidemiological features of the illness are unknown in a new area, the true number of infected people is underreported, and social isolation policies are introduced in time to hasten the disease's spread.

By offering data visualization in a variety of models, Saina and Samira 2021 have provided a good grasp of the data [16]. Additionally, they made an effort to look into modeling and forecasting, depending on each model. Additionally, they used the logistic function, linear regression, the well-known epidemiologic model SIR, and the time series model ARIMA to define and forecast the case count for four nations. To examine the effectiveness of models to forecast the number of cases, they created susceptible-infected-recovered (SIR) models and regression models for the contagious disease. Finally, the models were compared and suggested additional study.

Bhuju et al. 2020 have given a research paper to forecast the disease outbreak in Nepal and to describe the progression of the outbreak [28]. In their research, the SIR compartmental model was used to analytically examine the disease's transmission dynamics in Nepal. The model parameters were determined using reported data for Nepal from June 1 to June 17, 2020.

Balcha, A.A. (2020) used a Python function of the module polyfit technique to carry out the best curve fitting analysis in order to forecast the trend of COVID-19 cases in Ethiopia [2]. His study demonstrated how, based on the first ninety days of data, the distribution of the virus among the people will change over the ensuing ninety days. How many people will still have the Corona virus after 180 days?

A straightforward statistical study of the coronavirus (COVID-19) epidemic in Italy and Spain, two of the badly affected nations in Europe, has been provided by Chu J (2021) [6]. He has examined trends, modeled incidence, and approximated the basic reproduction number using two usual methods in epidemiology, the log-linear model and the SIR model, using data of the daily and accumulative incidence in both countries over a period of around one month after the first cases were approved in each nation. In the early phases of the outbreak, the SIR model's results indicated a sufficient fit to the collective incidence for the nation of Spain and its bulk-impacted regions, but they revealed a considerable underestimation for Italy and its most affected regions.

In 2022, Vidhi and Anmol investigated the COVID-19 outbreak's trend in India [20]. The total number of COVID-19 cases in India has been anticipated in real time using SMOreg, lBk, random forest, linear regression, and Gaussian processes, among other machine learning techniques. They chose the algorithms they utilized based on their broad ability to capture process nonlinearity and their adaptability in modeling time-dependent data. On the basis of 74 days of historical data going back to November 1, 2020 for India, estimates for the next 30 days were given. To check each model, they employed the RMSE, MAE, and MAPE parameters. They found that ARIMA (5, 2, 0) is the most effective predictor model for predicting mortality in India. They had the choice to measure the propagation using this model.

Understanding epidemic trends and providing insight on the epidemiological control of specific regions were the goals of Yanding and colleagues' 2022 study [25]. Additionally, the Prophet model's prediction demonstrated sufficient accuracy in the USA's daily COVID-19 new cases. Brazil and India were correctly predicted by the ARIMA model, which can assist in developing policies and measures for this outbreak in other nations.

In order to forecast the trajectory of the coronavirus disease 2019 (COVID-19) pandemic in Fiji, Singh, Lal, and Kotti (2022) used an implicit time-discrete SIR model that follows the transmission and recovery rate through time [19]. The Ministry of Health and Medical Services of Fiji provided the information that was utilized. Calculations based on the model's suggested time-based transference and improvement rates were made between May 4 and October 9, 2021. A 30-day forecast was made after the estimator functions for these rates were established. They found that the model was verified using the observed data for the affected and recovered cases from October 11, 2021, to December 9, 2021. A satisfactory fit of the outline between the artificial model and the surveyed COVID-19 data was found by statistical analysis.

The epidemiological models were examined in 2022 by Muhammad et al. with respect to Pakistan's COVID-19 data [13]. Through the use of Bayesian and time-series SIR (tSIR) approaches, the fundamental susceptible, infected, and recovered (SIR) model will be examined. Through time-series

SIR (tSIR), they discovered that when the reporting rate () value is below 1, instances are underreported.

A deterministic mathematical model was created by Adhikari et al. in 2021 and includes both imported and locally produced instances in addition to the numerous COVID-19 control measures put in place in Nepal [1]. They assessed important factors as well as the fundamental and practical reproductive numbers in Nepal using case data from both the epidemic's controlled and overgrown phases. They assessed the control methods used in Nepal using the model. Additionally, they used their model to forecast the long-term COVID-19 dynamics in Nepal and gave simulations to show how these checking techniques can stop outbreaks there.

1.3 Research Gap

In the case of COVID-19, there have been so many researchers engaged, but none of the researchers have found the detailed comparative results of the whole Nepal COVID-19 case using real data and models. So, this research is being forwarded to find comparative information with the help of models.

2. Reasearch Problems and Objectives

Due to the growing world population and their mobility all over the world, the risk of infectious disease is high. From 2019, there is a common big issue of COVID 19. Nepal is also a country affected by COVID-19. There are so many factors that affect COVID spread, such as an open border agreement with India, one of the COVID-19 nations most severely affected, low population awareness, delays in information, weak management in hospitals and health sectors, less study on COVID cases, and less chance to recognize and judge the results of regulating tactics in the context of nations like Nepal. So, the following are the research problems:

- What is the trend of suspected, infected, removed, and death cases of COVID-19 in Nepal?
- How can we use the SIR model in the case of the Corona virus disease?
- What will be the comparative evaluation of real data for COVID-19 with the models?

With reference to the above problems, we have the following objectives for the study:

- To find the trend of COVID-19 cases in Nepal by which COVID disease spread.
- To find the use of the solution of the SIR model in the disease.
- To find the comparative results of real data on COVID-19 in Nepal with the SIR model.

3. Methodology

3.1. Sources of Data

For the study, the secondary data on COVID-19 from March 2020 to August 2021 were extracted from the Government of Nepal, the Ministry of Health, the population Web site https://covid19.mohp.gov.np/ or https://heoc.mohp.gov.np, the WHO Coronavirus (COVID-19) Dashboard website: https://www.who.int, and the COVID-Coronavirus Statistics-Worldometer web site: https://www.worldometers.info>coronavirus. The secondary data was taken in terms of time period. The set of COVID-19 data series is arranged in chronological order.

3.2 Data Using Method and Models

The secondary time series data was applied to find the previous and future directions of disease spread. Corona virus disease (COVID-19) data provides information on the situation of disease conditions in the area. Time series data is used in comparing COVID-19 suspected, infected, recovered, and death cases for different geographical regions.

In this research, secondary data on COVID-19 has been gathered from authorized offices, and sources have been analyzed to make them easy to read and understand. Some tools for analyzing the gathered data and information have been used.

The solutions of a renowned model, SIR, have also been studied. The computer software MATLAB is used to plot the graphs with the help of parametric values obtained from the real data. The results of the models are compared graphically with the real collected data for COVID-19 and draw conclusions.

3.3 SIR Model

Kermack and McKendrick introduced the SIR model for the first time in 1927. In 1905–1906, they successfully applied it to a pandemic on the island of Bombay. Since then, the SIR model has been the subject of innumerable studies and applications [10].

The SIR model assumes that recovered people cannot become infected again and has compartments for susceptible (S), infected (I), and recovered (R) people.

Assume that S(t), I(t), and R(t) are the numbers of people in every compartment, resulting in S(t) + I(t) + R(t) = N and that N is a constant for the entire population. Three coupled ordinary differential equations provide the definitions of the rates of change in each of the compartments in the SIR model.

$$\frac{dS}{dt} = -\beta SI \quad (1)$$

$$\frac{dI}{dt} = \beta SI - \gamma I \quad (2)$$

$$\frac{dR}{dt} = \gamma I \quad (3)$$

where β = transmission rate , γ = recovery rate

- The size of the population is a constant (i.e., the birth rate is equal to the death rate; the immigration rate is equal to the emigration rate).
- The waiting or incubation period of the disease is ignored.
- The people mix homogeneously (i.e., anyone who gets into contact with an infected person would also be infected).
- The rate at which people become infected is proportional to the number of infected people present at that time.

Analytic solution of SIR model without vital dynamics

The analytical solution of above model is given as;

$$I(t) = N - S(t) + e \ln \left(\frac{S(t)}{S_0}\right) \quad (4)$$

$$S(t) = S_0 e^{-\frac{R(t)}{e}} \quad (5)$$

$$R(t) = \frac{\beta^2}{S_0}\left[\left(\frac{S_0}{e} - 1\right) + \alpha \tanh\left(\frac{\alpha\gamma t}{2} - \emptyset\right)\right] \quad (6)$$

where, $\alpha = \left[\left(\frac{S_0}{e} - 1\right)^2 + \frac{2S_0(N - S_0)}{e^2}\right]^{1/2}$, $\quad \emptyset = \frac{\tanh^{-1}\left(\frac{S_0}{e} - 1\right)}{\alpha}$

Here, $S(0) = S_0 > 0$, $I(0) = I_0 > 0$ and $R(0) = 0$

Taking lim as $t \to \infty$ on equation (5)

$$\lim_{t\to\infty} S(t) = S_\infty > 0$$

So, $I(t) = N - S_\infty + e \ln\left(\frac{S_\infty}{S_0}\right)$.

i.Finding I_{max} (Maximum number of infection):
The maximum occurs at where $\frac{dI}{dT} = 0$ and $s = e$ and so $s = \frac{\gamma}{\beta} = e$.
ii.$I_{max} = I_0 + S_0 - e + e \ln\left(\frac{e}{S_0}\right)$.

Basic reproductive number (R_0)

It is defined as the total number of secondary illnesses brought on by a single infected person in the community who is entirely susceptible. The most crucial measure in epidemiology is R0, which gives us an indication of how the disease spreads over the entire community. [4].

If $R_0 > 1$, then disease will epidemic (high predictive risk of an epidemic event).

If $R_0 < 1$, then disease will die out (low risk of the occurrence of an epidemic event) [11].

In this case, the basic reproductive number R0 can be extracted with the help of ordinary differential equations, assuming the relationship between the rate of infection (betta) and the rate of recovery (gamma) [5].

If $R_0 \geq 1$, then disease will spread.

If $R_0 = 1$, then the disease will be endemic.

Model Parameters Finding

In this study, we used a SIR model and computer software programming to estimate various COVID-19 epidemic curve parameters for Nepal over the given time.

The different parameters are the transmission rate(β), recovery rate(γ), and basic reproductive number(R_0). $R_0 = \frac{\beta N}{\gamma}$. When $N \approx S$, $R_0 = \frac{\beta}{\gamma}$.

$\gamma = \frac{1}{T}$, where $T$is the time for recovery.

If the time changes dt=α, then $\gamma = \frac{R(t+1)-R(t)}{I(t)}$.

MATLAB Software

Matlab (Matrix Laboratory) is a proprietary numerical computing environment and multi-paradigm programming language created by Math Works. Matlab enables matrix manipulation, user interface design, and connectivity with other programming languages. In this work, graphs are drawn using MATLAB R2015a to determine the trend of the Corona virus in Nepal and to compare and contrast the graphs with the data and model.

4. Results and discussion

This study deals with the results, analysis, and discussion concerning the COVID-19 real cases and model. The secondary data on disease were collected and analyzed according to the research objectives using different suitable figures with the help of MATLAB software.

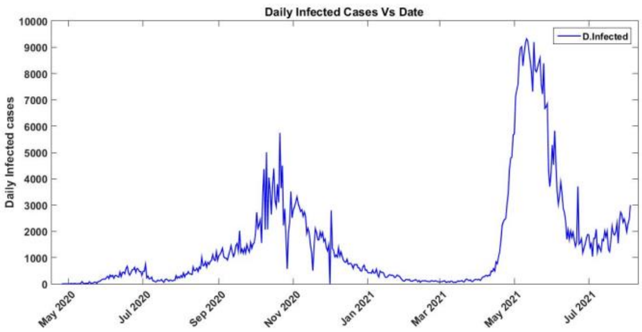

Fig.1. Daily Infected Cases vs. Time (May 2020 to August 2021)

Figure 1 represents the daily infected cases of real COVID-19 data in Nepal from May 2020 to August 2021. It is seen that as the number of days increases, the value of infected cases increases up to November and then decreases up to April 2021. Moreover, the infected case again increases very quickly and decreases. Maximum infection is seen in May 2020 and after May 2021. From February 2021 to April 2021, the infection was very low.

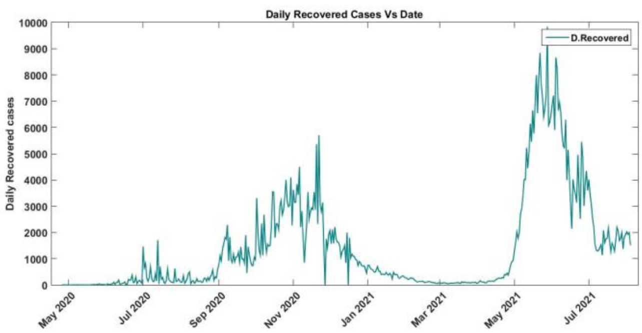

Fig.2. Daily Recovered Cases vs. Time

Figure (2) represents the daily recovered cases of real COVID-19 data in Nepal from May 2020 to August 2021. It is seen that as the number of days increases, the number of infected cases increases up to November and then decreases up to April 2021. Moreover, the infected case again increases very quickly and decreases. Maximum infection is seen in May 2020 and after May 2021. In March 2021, the infection was very low.

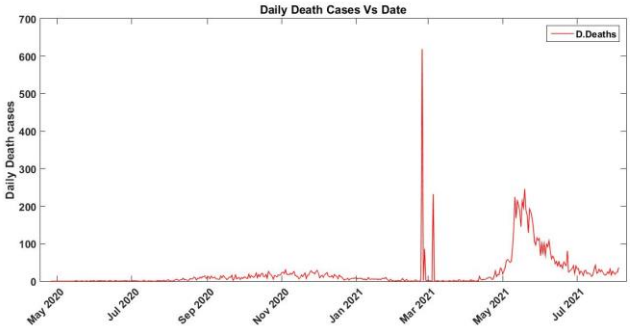

Fig.3. Daily Death Cases vs. Time

Figure (3) represents the daily death cases of real COVID-19 data in Nepal from May 2020 to August 2021. It is seen that as the number of days increases, the number of daily death cases slowly increases up to November and then decreases up to April 2021. Moreover, the number of deaths again increases very quickly and rapidly decreases. Again, the number of death cases increases from May to June and decreases. Maximum death is seen in May 2020, in March 2021, and in June 2021.

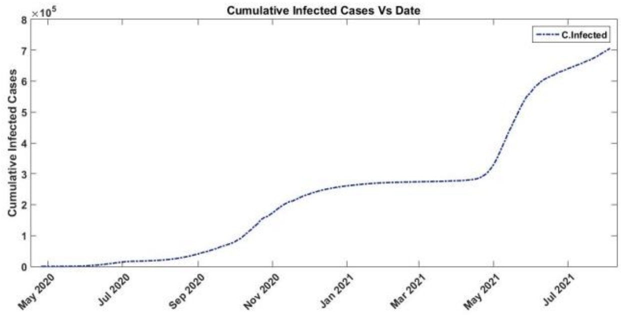

Fig.4. Cumulative Infected Cases vs. Time

Figure (4) represents the cumulative infected cases of real COVID-19 data in Nepal from May 2020 to August 2021. The infected case increases rapidly from November, and so the curve is very speedily up, as shown in the figure.

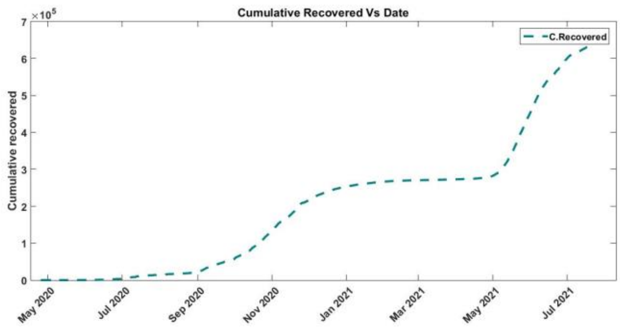

Fig.5. Cumulative Recovered Cases vs. Time

Figure (5) represents the daily cumulative recovered cases of real COVID-19 data in Nepal from May 2020 to August 2021. The recovered case increases rapidly from November, and so the curve is very speedily up, as shown in the figure.

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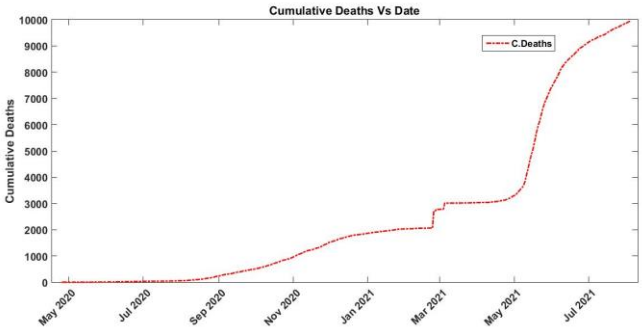

Fig.6. Cumulative Death Cases vs. Time

Figure (6) represents the cumulative death cases of real COVID-19 data in Nepal from May 2020 to August 2021. The death case increases from September, and so the curve very quickly up, as shown in the figure.

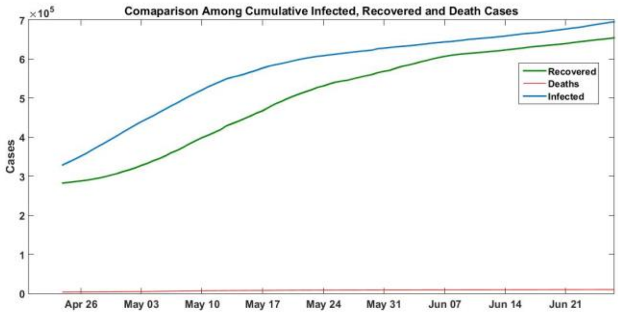

Fig.7. Comparison among the Cases vs. Time

Figure (7) represents the comparison among the cumulated infected, recovered, and death cases of real COVID-19 data in Nepal from April 2020 to July 2020. It is seen that as the number of days increases, the cases of infected and recovered cases increase sufficiently in comparison to death cases.

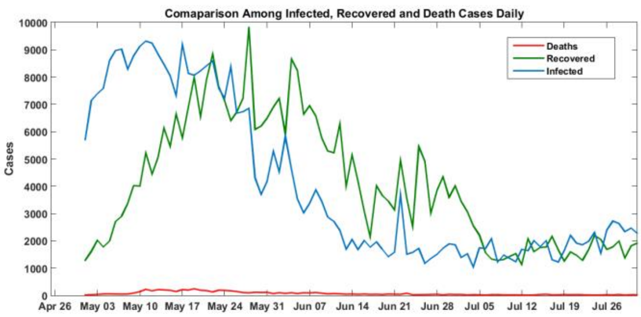

Fig.8. Comparison among the Cases vs. Time

Figure (8) represents the comparison among the daily infected, recovered, and death cases of real COVID-19 data in Nepal from April 2020 to August 2020. It is seen that as the number of days increases, the value of infected, recovered, and death cases also increases up to May and then decreases. Moreover, all of the cases have a maximum value in May.

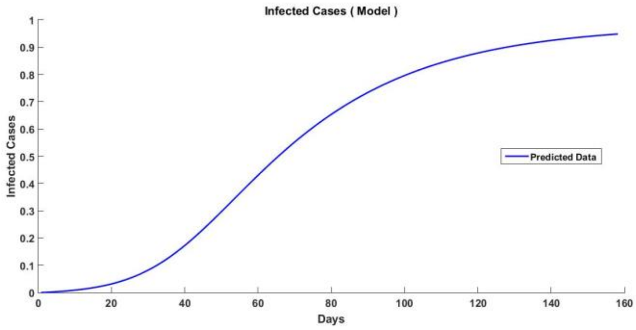

Fig.9. Predicted infected cases vs. Time

Figure (9) represents the graph of daily infected predicted cases with the help of MATLAB software. It is seen that as the number of days increases, the value of predicted infected cases increases.

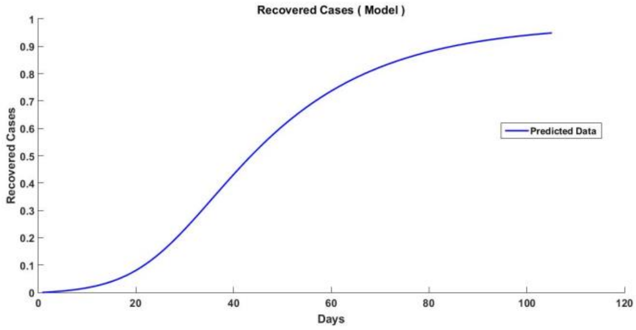

Fig.10. Predicted recovered cases vs. Time

Figure (10) represents the graph of daily recovered predicted cases with the help of MATLAB software. It is seen that as the number of days increases, the value of predicted recovered cases increases.

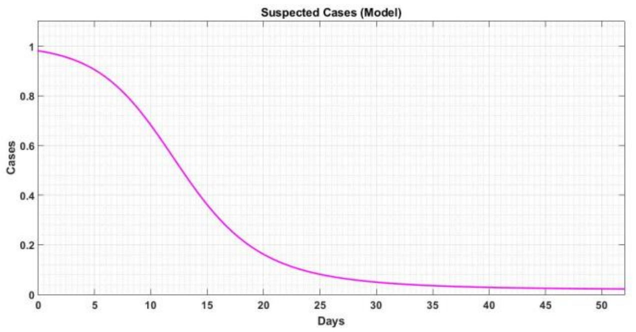

Fig.11. Predicted Suspected Cases vs. Time

Figure (11) represents the graph of daily predicted suspected cases with the help of MATLAB software. It is seen that as the number of days increases, the value of predicted suspected cases decreases, as shown in the figure.

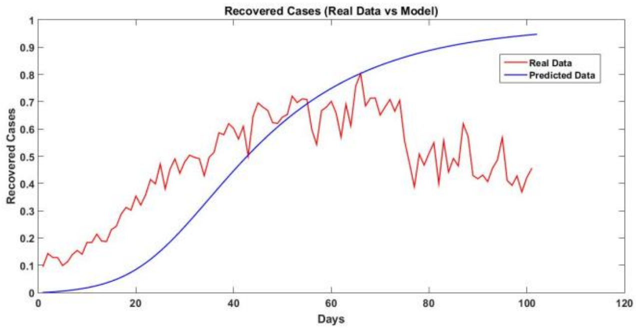

Fig.12. Recovered Cases Real and Model vs. Time

Figure (12) represents the graphs of daily recovered cases of real COVID-19 data in Nepal from April 2020 to July 2020 and the SIR Model using suitable parametric values. It is seen that as the number of days increases, the value of recovered cases increases from both methods (the real data method and the model method). Moreover, the predicted graph of recovered cases from the model almost matches the graph of recovered cases from real COVID-19 data from Nepal.

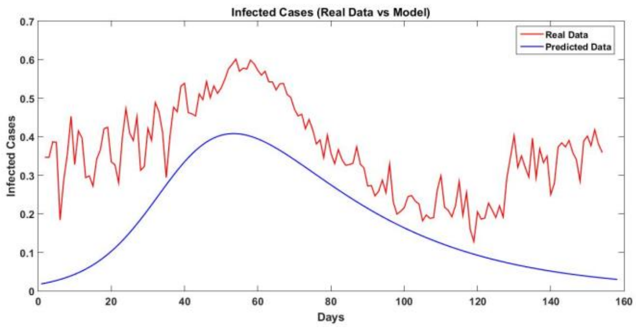

Fig.13. Infected Cases Real and Model vs. Time

Figure (13) shows the graphs of daily infected cases of real COVID-19 data in Nepal from April 2020 to July 2020 and the SIR Model using suitable parametric values. It is seen that as the number of days increases, the value of infected cases increases from both methods (the real data method and the model method) up to a date and then decreases in the same pattern. Moreover, the predicted graph of infected cases from the model almost matches the graph of infected cases in real COVID-19 data from Nepal.

5. Conclusion and Suggession

5.1. Conclusion

In recent days, COVID-19 cases have created a major problem for human beings. It has also created a major health problem in Nepal. This study mainly focuses on the trend of suspected, infected, recovered, and death cases in Nepal using real COVID-19 data taken from different reliable secondary sources using computer software. To study the trend and comparison among the cases and the model, the real data of the COVID and SIR models were applied. We summarized the study with the help of graphs of real data and models with suitable parameters.

Figures 1–3 are the graphs of real data on the daily cases of infected cases recovered and deaths in Nepal in a specific time period. Figures 4 to 6 are also graphs from real data on the same periods in cumulated forms. In figures 7 and 8, we have shown the comparison among the cases. All the figures from 1 to 8 have given the actual situation in Nepal at that time. The graphs have been drawn with the help of the computer software MATLAB.

Figures 9 to 11 represent the graphs of predicted data using some suitable parameters obtained from actual data with the help of MATLAB software. The figures show the same types of patterns as real data figures. The trend of COVID-19 cases is increasing from May 2020 to November 2020, decreasing from November 2020 to April 2021, increasing from June 2021 to June 2021, and decreasing from June 2021 to July 2021. Infected cases are high in November 2020 and in May to June 2021.Recovered cases are high in November to December 2020 and in May to June 2021.

And in the last, we have compared the graphs made by MATLAB software obtained from real data of COVID-19 Nepal and model SIR. We have come to the conclusion that the predicted data from the model almost matches the real data of COVID in Nepal.

5.2 Suggestions

This study primarily utilizes secondary COVID-19 data to identify trends and make forecasts using the SIR model with the use of MATLAB software. To determine the nature of the transmission of disease cases, in particular death and birth cases, more research may be done. Additionally, we can examine COVID situations using additional statistical and mathematical techniques.

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